CLAIMS

What is claimed is:

1. A biphasic defibrillation waveform comprising:

a positive voltage phase beginning at about zero volts and having an initial positive voltage magnitude greater than zero volts, the positive voltage phase having a first positively sloped portion extending from the initial positive voltage magnitude to a maximum positive voltage magnitude greater than the initial positive voltage magnitude; and

a negative voltage phase having an initial maximum negative voltage magnitude less than zero volts extending from the maximum positive voltage magnitude of the positive voltage phase, the negative voltage phase having a second positively sloped portion extending from the initial maximum negative voltage magnitude to a terminal negative voltage magnitude greater than the initial maximum negative voltage magnitude.

2. The waveform, as set forth in claim 1, wherein the initial positive voltage magnitude is in a range from about 0 volts to about 50 volts.

3. The waveform, as set forth in claim 1, wherein the maximum positive voltage magnitude is in a range from about 200 volts to about 400 volts.

4. The waveform, as set forth in claim 1, wherein the initial maximum negative voltage magnitude is in a range from about -200 volts to about -400 volts.

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5. The waveform, as set forth in claim 1, wherein the terminal negative voltage magnitude is in a range from about -50 volts to about 0 volts.

6. The waveform, as set forth in claim 1, wherein the first positively sloped portion comprises a substantially linear slope.

7. The waveform, as set forth in claim 1, wherein the first positively sloped portion comprises a continuously increasing slope.

8. The waveform, as set forth in claim 1, wherein the first positively sloped portion comprises a continuously decreasing slope.

9. The waveform, as set forth in claim 1, wherein the second positively sloped portion comprises a substantially linear slope.

10. The waveform, as set forth in claim 1, wherein the second positively sloped portion comprises a continuously increasing slope.

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11. The waveform, as set forth in claim 1, wherein the second positively sloped portion comprises a continuously decreasing slope.

12. A biphasic defibrillation waveform comprising:

a positive voltage phase having an initial voltage magnitude equal to about zero volts and having a first positively sloped portion extending from the initial voltage magnitude to a maximum positive voltage magnitude greater than the initial voltage magnitude; and

a negative voltage phase having an initial negative voltage magnitude less than or equal to zero volts extending from the maximum positive voltage magnitude of the positive voltage phase, the negative voltage phase having a second sloped portion

extending from the initial negative voltage magnitude to a terminal negative voltage having a magnitude less than or equal to zero volts.

13. The waveform, as set forth in claim 12, wherein the maximum positive voltage magnitude is in a range from about 200 volts to about 400 volts.

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14. The waveform, as set forth in claim 12, wherein the initial negative voltage magnitude is in a range from about 0 volts to about -400 volts.

15. The waveform, as set forth in claim 12, wherein the terminal negative voltage magnitude is in a range from about 0 volts to about -400 volts.

16. The waveform, as set forth in claim 12, wherein the first positively sloped portion comprises a substantially linear slope.

17. The waveform, as set forth in claim 12, wherein the first positively sloped portion comprises a continuously increasing slope.

18. The waveform, as set forth in claim 12, wherein the first positively sloped portion comprises a continuously decreasing slope.

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19. The waveform, as set forth in claim 12, wherein the second sloped portion comprises a positive slope.

20. The waveform, as set forth in claim 19, wherein the second sloped portion comprises a substantially linear slope.

21. The waveform, as set forth in claim 19, wherein the second positively sloped portion comprises a continuously increasing slope.

22. The waveform, as set forth in claim 19, wherein the second positively sloped portion comprises a continuously decreasing slope.

23. The waveform, as set forth in claim 12, wherein the second sloped portion comprises a negative slope.

24. The waveform, as set forth in claim 23, wherein the second sloped portion comprises a substantially linear slope.

25. The waveform, as set forth in claim 23, wherein the second positively sloped portion comprises a continuously increasing slope.

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26. The waveform, as set forth in claim 23, wherein the second positively sloped portion comprises a continuously decreasing slope.

27. A biphasic defibrillation waveform comprising:

a positive voltage phase having an initial maximum positive voltage magnitude greater than zero volts and having a first negatively sloped portion extending from the initial maximum positive voltage magnitude to a terminal positive voltage magnitude less than the initial maximum positive voltage magnitude; and

a negative voltage phase having an initial negative voltage magnitude less than or equal to zero volts extending from the terminal positive voltage magnitude of the positive voltage phase, the negative voltage phase having a second sloped portion

extending from the initial negative voltage magnitude to a terminal negative voltage having a magnitude less than or equal to zero volts.

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28. The waveform, as set forth in claim 27, wherein the initial maximum positive voltage magnitude is in a range from about 200 volts to about 400 volts.

29. The waveform, as set forth in claim 27, wherein the terminal positive voltage magnitude is in a range from about 50 volts to greater than 0 volts.

30. The waveform, as set forth in claim 27, wherein the initial negative voltage magnitude is in a range from about 0 volts to about -400 volts.

31. The waveform, as set forth in claim 27, wherein the terminal negative voltage magnitude is in a range from about 0 volts to about -400 volts.

32. The waveform, as set forth in claim 27, wherein the first negatively sloped portion comprises a substantially linear slope.

33. The waveform, as set forth in claim 27, wherein the first negatively sloped portion comprises a continuously increasing slope.

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34. The waveform, as set forth in claim 27, wherein the first negatively sloped portion comprises a continuously decreasing slope.

35. The waveform, as set forth in claim 27, wherein the second sloped portion comprises a positive slope.

36. The waveform, as set forth in claim 35, wherein the second sloped portion comprises a substantially linear slope.

37. The waveform, as set forth in claim 35, wherein the second positively sloped portion comprises a continuously increasing slope.

38. The waveform, as set forth in claim 35, wherein the second positively sloped portion comprises a continuously decreasing slope.

39. The waveform, as set forth in claim 27, wherein the second sloped portion comprises a negative slope.

40. The waveform, as set forth in claim 39, wherein the second sloped portion comprises a substantially linear slope.

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41. The waveform, as set forth in claim 39, wherein the second positively sloped portion comprises a continuously increasing slope.

42. The waveform, as set forth in claim 39, wherein the second positively sloped portion comprises a continuously decreasing slope.

43. A biphasic defibrillation waveform comprising:

a positive voltage phase having an initial positive voltage having a magnitude greater than or equal to zero volts and having a first sloped portion extending from the initial positive voltage to a terminal positive voltage having magnitude greater than or equal to zero volts; and

a negative voltage phase having an initial negative voltage having a magnitude less than or equal to zero volts extending from the terminal positive voltage of the positive voltage phase, the negative voltage phase having a second sloped portion extending from the initial negative voltage to a terminal negative voltage having a magnitude less than or equal to zero volts.

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44. The waveform, as set forth in claim 43, wherein the initial positive voltage magnitude is in a range from about 0 volts to about 400 volts.

45. The waveform, as set forth in claim 43, wherein the terminal positive voltage magnitude is in a range from about 0 volts to about 400 volts.

46. The waveform, as set forth in claim 43, wherein the initial negative voltage magnitude is in a range from about 0 volts to about -400 volts.

47. The waveform, as set forth in claim 43, wherein the terminal negative voltage magnitude is in a range from about 0 volts to about -400 volts.

48. The waveform, as set forth in claim 43, wherein the first sloped portion comprises a positive slope.

49. The waveform, as set forth in claim 48, wherein the first sloped portion comprises a substantially linear slope.

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50. The waveform, as set forth in claim 48, wherein the first sloped portion comprises a continuously increasing slope.

51. The waveform, as set forth in claim 48, wherein the first sloped portion comprises a continuously decreasing slope.

52. The waveform, as set forth in claim 43, wherein the first sloped portion comprises a negative slope.

53. The waveform, as set forth in claim 52, wherein the first sloped portion comprises a substantially linear slope.

54. The waveform, as set forth in claim 52, wherein the first sloped portion comprises a continuously increasing slope.

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55. The waveform, as set forth in claim 52, wherein the first sloped portion comprises a continuously decreasing slope.

56. The waveform, as set forth in claim 43, wherein the second sloped portion comprises a positive slope.

57. The waveform, as set forth in claim 56, wherein the second sloped portion comprises a substantially linear slope.

58. The waveform, as set forth in claim 56, wherein the second positively sloped portion comprises a continuously increasing slope.

59. The waveform, as set forth in claim 56, wherein the second positively sloped portion comprises a continuously decreasing slope.

60. The waveform, as set forth in claim 43, wherein the second sloped portion comprises a negative slope.

61. The waveform, as set forth in claim 60, wherein the second sloped portion comprises a substantially linear slope.

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62. The waveform, as set forth in claim 60, wherein the second positively sloped portion comprises a continuously increasing slope.

63. The waveform, as set forth in claim 60, wherein the second positively sloped portion comprises a continuously decreasing slope.

64. A method of generating a biphasic defibrillation waveform comprising the acts of:

generating a positive voltage phase having an initial positive voltage having a magnitude greater than or equal to zero volts and having a first sloped portion extending from the initial positive voltage to a terminal positive voltage having magnitude greater than or equal to zero volts; and

generating a negative voltage phase having an initial negative voltage having a magnitude less than or equal to zero volts extending from the terminal positive voltage of the positive voltage phase, the negative voltage phase having a second sloped portion extending from the initial negative voltage to a terminal negative voltage having a magnitude less than or equal to zero volts.

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65. The method, as set forth in claim 64, wherein the initial positive voltage magnitude is in a range from about 0 volts to about 400 volts.

66. The method, as set forth in claim 64, wherein the terminal positive voltage magnitude is in a range from about 0 volts to about 400 volts.

67. The method, as set forth in claim 64, wherein the initial negative voltage magnitude is in a range from about 0 volts to about -400 volts.

68. The method, as set forth in claim 64, wherein the terminal negative voltage magnitude is in a range from about 0 volts to about -400 volts.

69. The method, as set forth in claim 64, wherein the first sloped portion comprises a positive slope.

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70. The method, as set forth in claim 69, wherein the first sloped portion comprises a substantially linear slope.

71. The method, as set forth in claim 69, wherein the first sloped portion comprises a continuously increasing slope.

72. The method, as set forth in claim 69, wherein the first sloped portion comprises a continuously decreasing slope.

73. The method, as set forth in claim 64, wherein the first sloped portion comprises a negative slope.

74. The method, as set forth in claim 73, wherein the first sloped portion comprises a substantially linear slope.

75. The method, as set forth in claim 73, wherein the first sloped portion comprises a continuously increasing slope.

76. The method, as set forth in claim 73, wherein the first sloped portion comprises a continuously decreasing slope.

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77. The method, as set forth in claim 64, wherein the second sloped portion comprises a positive slope.

78. The method, as set forth in claim 77, wherein the second sloped portion comprises a substantially linear slope.

79. The method, as set forth in claim 77, wherein the second positively sloped portion comprises a continuously increasing slope.

80. The method, as set forth in claim 77, wherein the second positively sloped portion comprises a continuously decreasing slope.

81. The method, as set forth in claim 64, wherein the second sloped portion comprises a negative slope.

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82. The method, as set forth in claim 81, wherein the second sloped portion comprises a substantially linear slope.

83. The method, as set forth in claim 81, wherein the second positively sloped portion comprises a continuously increasing slope.

84. The method, as set forth in claim 81, wherein the second positively sloped portion comprises a continuously decreasing slope.

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85. A defibrillation waveform generator comprising:

an arrhythmia detector adapted to be coupled to a heart, the arrhythmia detector delivering a detection signal in response to detecting fibrillation in the heart;

a charging circuit coupled to a capacitor, the charging circuit charging the capacitor to a given voltage;

a controller operably coupled to the arrhythmia detector to receive the detection signal, the controller delivering a first control signal, a second control signal, and a third control signal in response to receiving the detection signal;

a voltage-to-frequency convertor coupled to the controller to receive the first control signal, the voltage-to-frequency convertor delivering a frequency signal having a frequency correlative to the first control signal;

a pulse width modulator coupled to the controller to receive the second control signal and coupled to the voltage-to-frequency convertor to receive the frequency signal, the pulse width modulator delivering a pulse width modulated signal having a frequency correlative to the frequency signal and having a duty cycle correlative to the second control signal; and

a switching circuit adapted to be coupled between the capacitor and the heart, the switching circuit being coupled to the controller to receive the third control signal and to the pulse width modulator to receive the pulse width modulated signal, the switching circuit controllably discharging the capacitor across the heart to deliver a defibrillation waveform in response to the third control signal and the pulse width modulated signal.

86. The generator, as set forth in claim 85, wherein the switching circuit comprises a first switch being coupled between the capacitor and the heart, the first switch being coupled to the controller to receive the third signal, the first switch being closed in response to receiving the third signal, and wherein the switching circuit comprises a second switch being coupled between the heart and the capacitor, the second switch being coupled to the pulse width modulator to receive the pulse width modulated signal, the second switch being repeatedly opened and closed in response to receiving the pulse width modulated signal to produce a positive phase waveform in the heart.

87. The generator, as set forth in claim 86, wherein the switching circuit comprises a third switch being coupled between the capacitor and the heart, the third switch being coupled to the controller to receive the third signal, the third switch being closed in response to receiving the third signal, and wherein the switching circuit comprises a fourth switch being coupled between the heart and the capacitor, the fourth switch being coupled to the pulse width modulator to receive the pulse width modulated signal, the fourth switch being repeatedly opened and closed in response to receiving the pulse width modulated signal to produce a negative phase waveform in the heart.

88. A defibrillation waveform generator comprising:

an arrhythmia detector adapted to be coupled to a heart, the arrhythmia detector delivering a detection signal in response to detecting fibrillation in the heart;

a charging circuit coupled to a first capacitor and to a second capacitor, the charging circuit charging the first capacitor and the second capacitor to a respective given voltage;

a controller operably coupled to the arrhythmia detector to receive the detection signal, the controller delivering a first control signal, a second control signal, and a third control signal in response to receiving the detection signal;

a voltage-to-frequency convertor coupled to the controller to receive the first control signal, the voltage-to-frequency convertor delivering a frequency signal having a frequency correlative to the first control signal;

a pulse width modulator coupled to the controller to receive the second control signal and coupled to the voltage-to-frequency convertor to receive the frequency signal, the pulse width modulator delivering a pulse width modulated signal having a frequency correlative to the frequency signal and having a duty cycle correlative to the second control signal; and

a switching circuit adapted to be coupled between the first and second capacitors and the heart, the switching circuit being coupled to the controller to receive the third control signal and to the pulse width modulator to receive the pulse width modulated signal, the switching circuit controllably discharging the first capacitor across the heart to deliver a positive phase defibrillation waveform in response to the third control signal and the pulse width modulated signal, and the switching circuit controllably discharging the second capacitor across the heart to deliver a negative phase defibrillation waveform in response to the third control signal and the pulse width modulated signal.

89. The generator, as set forth in claim 88, wherein the switching circuit comprises a first switch being coupled between the first capacitor and the heart, the first switch being coupled to the controller to receive the third signal, the first switch being closed in response to receiving the third signal, and wherein the switching circuit comprises a second switch being coupled between the heart and the capacitor, the second switch being coupled to the pulse width modulator to receive the pulse width modulated signal, the second switch being repeatedly opened and closed in response to receiving the pulse width modulated signal to produce a positive phase waveform in the heart.

90. The generator, as set forth in claim 89, wherein the switching circuit comprises a third switch being coupled between the second capacitor and the heart, the third switch being coupled to the controller to receive the third signal, the third switch being closed in response to receiving the third signal, and wherein the switching circuit comprises a fourth switch being coupled between the heart and the capacitor, the fourth switch being coupled to the pulse width modulator to receive the pulse width modulated signal, the fourth switch being repeatedly opened and closed in response to receiving the pulse width modulated signal to produce a negative phase waveform in the heart.

91. A cardiac stimulator for treating fibrillations comprising:

an implantable case containing:

an atrial sensing circuit adapted to deliver an atrial signal correlative to a condition of an atrium of a heart;

a ventricular sensing circuit adapted to deliver a ventricular signal correlative to a condition of a ventricle of the heart;

an inductor-less pulse generator adapted to deliver pulse width modulated electrical stimulation to the ventricle; and

a control circuit coupled to the ventricular sensing circuit to receive the ventricular signal, the control circuit directing the pulse generator to deliver pulse width modulated electrical stimulation to the ventricle in response to classifying a ventricular tachyarrhythmia as a fibrillation.

92. A cardiac stimulator comprising:

means for determining whether a fibrillation exists in a ventricle;

means for charging at least one capacitor; and

means for discharging the at least one capacitor in a pulse width modulated manner to the ventricle to create a defibrillation waveform for treating the fibrillation.

93. A method of treating fibrillation comprising the acts of:

(a) determining whether a fibrillation exists in a ventricle;

(b) charging at least one capactitor; and

(c) electrically stimulating the ventricle with a waveform to treat the fibrillation by discharging the at least one capacitor in a pulse width modulated manner.

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